

Observed Structure and Characteristics of Cold Pools over Tropical Oceans using Scatterometer Vector Wind Retrievals

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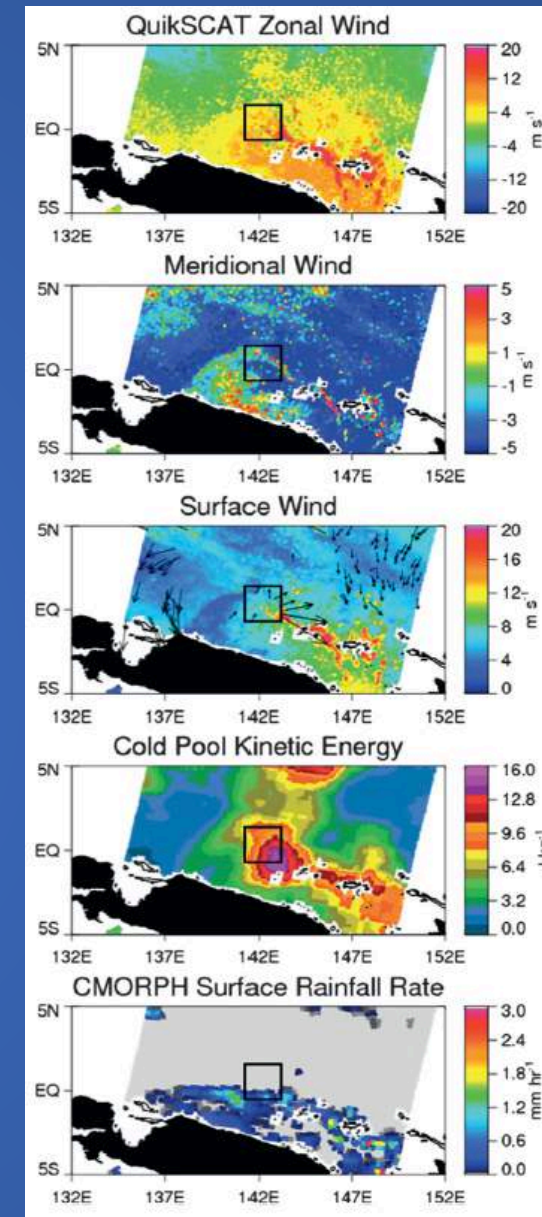
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Background

- Cold pool activity can significantly impact horizontal wind velocities at 10-30 km grid scale, leading to significant Inhomogenities in GCMs. (Tompkins 2001; Ross et al. 2004; Zuidema et al. 2012).
- Elsaesser et al. (2013) utilized the QuikSCAT data over tropical oceans to assess the relationship between the surface winds and cold pools using cold pool kinetic energy (CPKE).
- CPKE used the anomalies in the horizontal wind and since variance in surface winds over tropical oceans is likely related to cold pool outflow or mesoscale downdrafts from nearby regions of convection.

- Elsaesser et al. (2013) did not consider rain contamination and assumed that CPKE was capturing actual wind variations around the rainfall maximum.
- Kilpatrick et al. (2015) used ASCAT data after limiting rain contamination to observe MCS downdrafts using divergence.
- Kilpatrick et al. (2015) found that ASCAT cannot detect the convective-scale gust fronts, but can detect mesoscale downdrafts corresponding to cold pools.



Courtesy: Elsaesser et al. (2013)

Motivation and Goals of this study

- We hypothesize that an approach based on gradient features (GFs) can be used to identify the cold pools over tropical oceans.
- Cold pools form a boundary of gust front, thus creating an area of steep gradients in horizontal winds.
- Divergence and vorticity are noisier to identify the areas of steep gradients in the horizontal wind, thus gradient of horizontal wind is calculated using:

$$\nabla \vec{V} = \begin{bmatrix} \frac{\partial u}{\partial x} & \frac{\partial v}{\partial x} \\ \frac{\partial u}{\partial y} & \frac{\partial v}{\partial y} \end{bmatrix}$$

- After calculating gradient in the horizontal wind, Sobel technique and convex hull algorithm was implemented to identify the perimeters of the GFs.
- Properties corresponding to individual GFs like eccentricity, area, weighted centroid etc. were calculated.
- Identification of the boundary of the density current was performed using divergence ($\nabla \cdot \vec{V}$) and vorticity ($\nabla \times \vec{V}$).
- WRF simulation was ran and GFs were obtained using model winds to test our hypotheses.

Data used in this study

Observations

- ASCAT Metop-A dataset from Remote sensing systems (REMSS) is used at 12.5km resolution for the period of 2007-2015.
- This dataset uses TRMM Microwave Imager (TMI), GPM Microwave imager (GMI), Advanced Microwave Scanning Radiometer-2 (AMSR-2) and WindSat to determine if rain is present within 3 hours at the location of ASCAT observation.
- CPC Morphing Technique (CMORPH) precipitation dataset for the above period at 8km and 30-min resolution is used.
- Modern-Era Retrospective analysis for Research and Applications (MEERA-2) products were used to identify background fields.
- S-Polka Radar data from DYNAMO dataset archive was used to visualize convection over Indian Ocean corresponding to ASCAT swaths and WRF simulations.

Modeling Framework

- WRF with ARW core was run on a nested grid of 27-9-3 km using initial conditions from GFS for the period of Active MJO-1 (19th and 20th October 2011) with following schemes:

Physics	Parameterization Scheme
Longwave Radiation	RRTMG
Shortwave Radiation	RRTMG
Microphysics	Thompson
Boundary Layer	YSU
Cumulus	Tiedtke (27km and 9km)

- Convection was allowed explicitly in 3km domain.

Methodology

- Post the identification of GFs globally, a comparison was drawn between ASCAT and MERRA-2 to see whether the reanalysis dataset is able to resolve the background dynamics.
- Surface sensible and latent heat fluxes were calculated using MERRA-2 background field products and ASCAT winds.
- Precipitation from CMORPH was collocated with the gradient features within 8 degrees of the centroid.
- WRF's 3 km dataset was regridded to 12.5 km and GFs were calculated for the domain.
- To study the thermodynamic structure of GFs, virtual temperature (T_v) was calculated from model parameters and GFs were overlaid on T_v to see whether they collocate or not.

Results

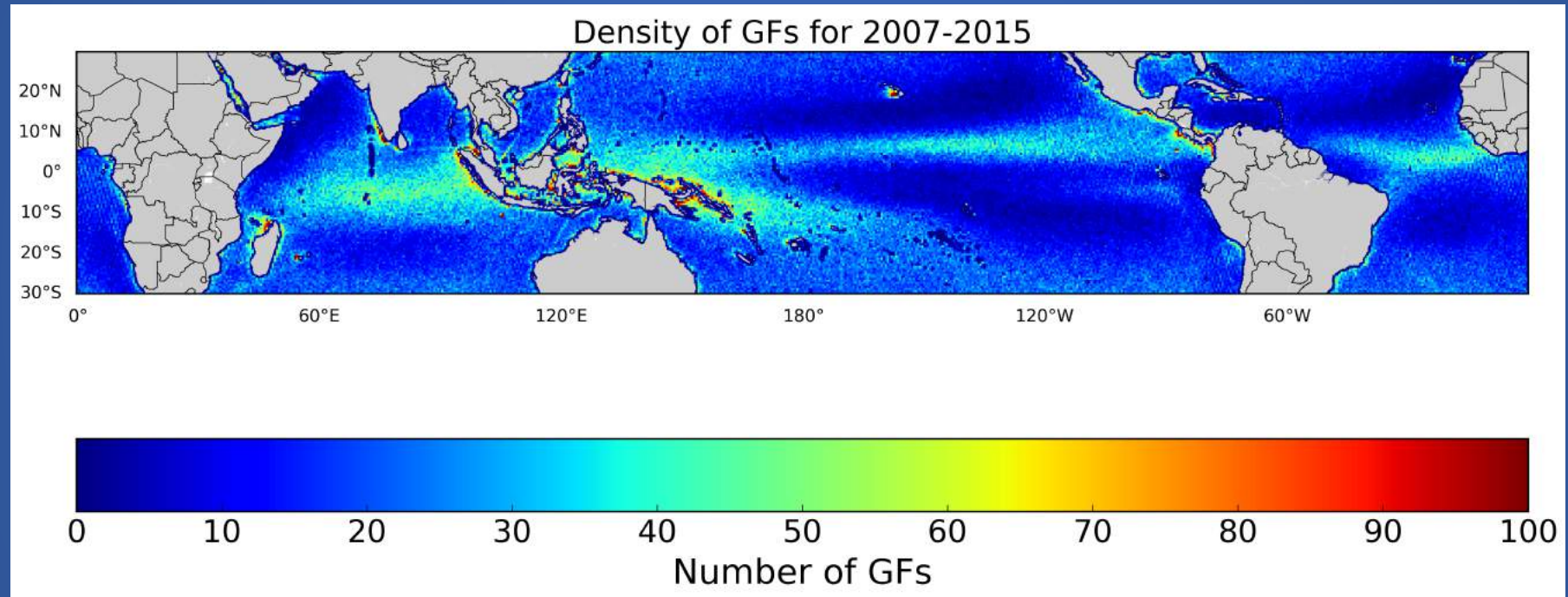


Fig.1 Density of GFs in a 0.5° grid box for 2007-2015

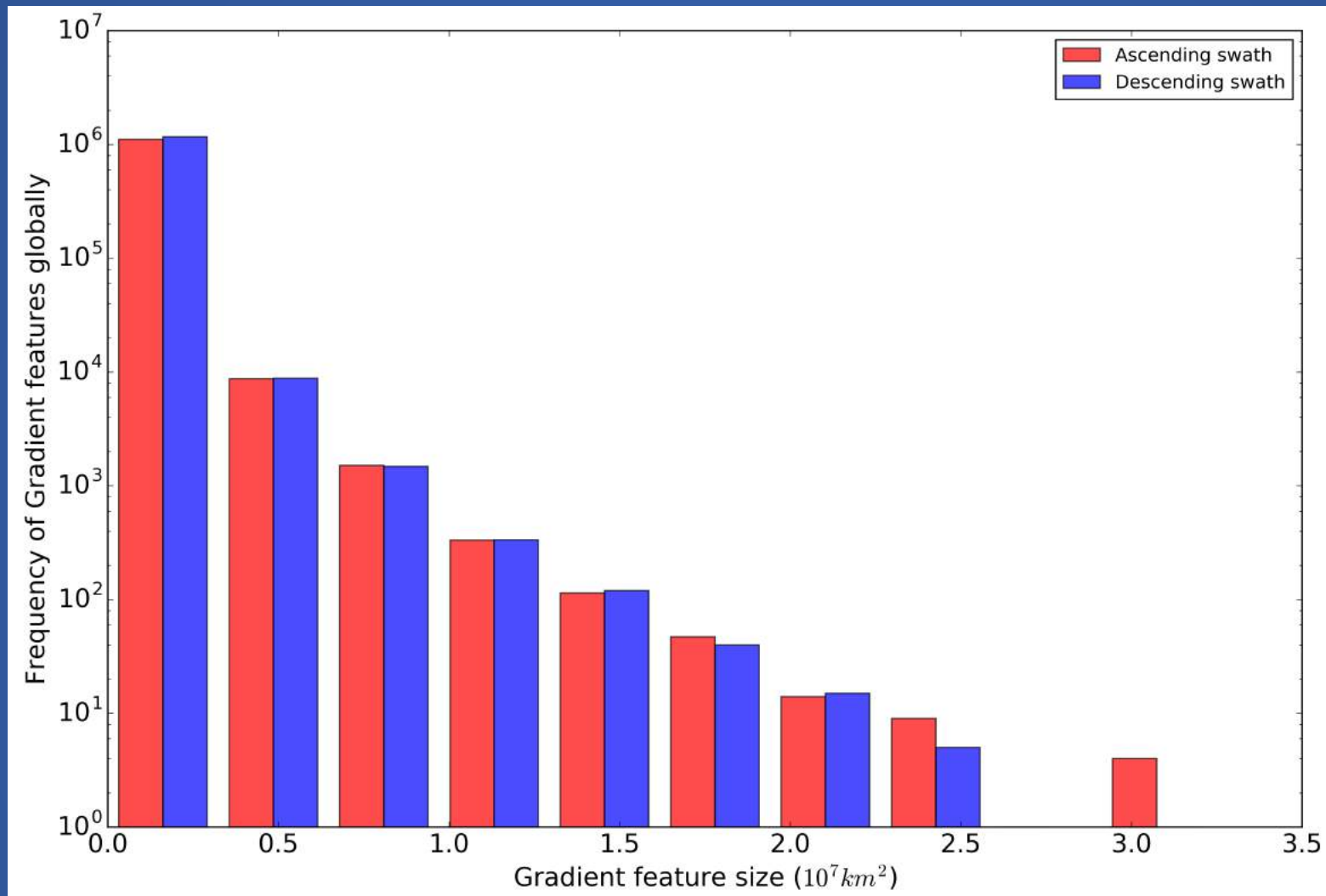


Fig.2 Global distribution of GFs based on their sizes

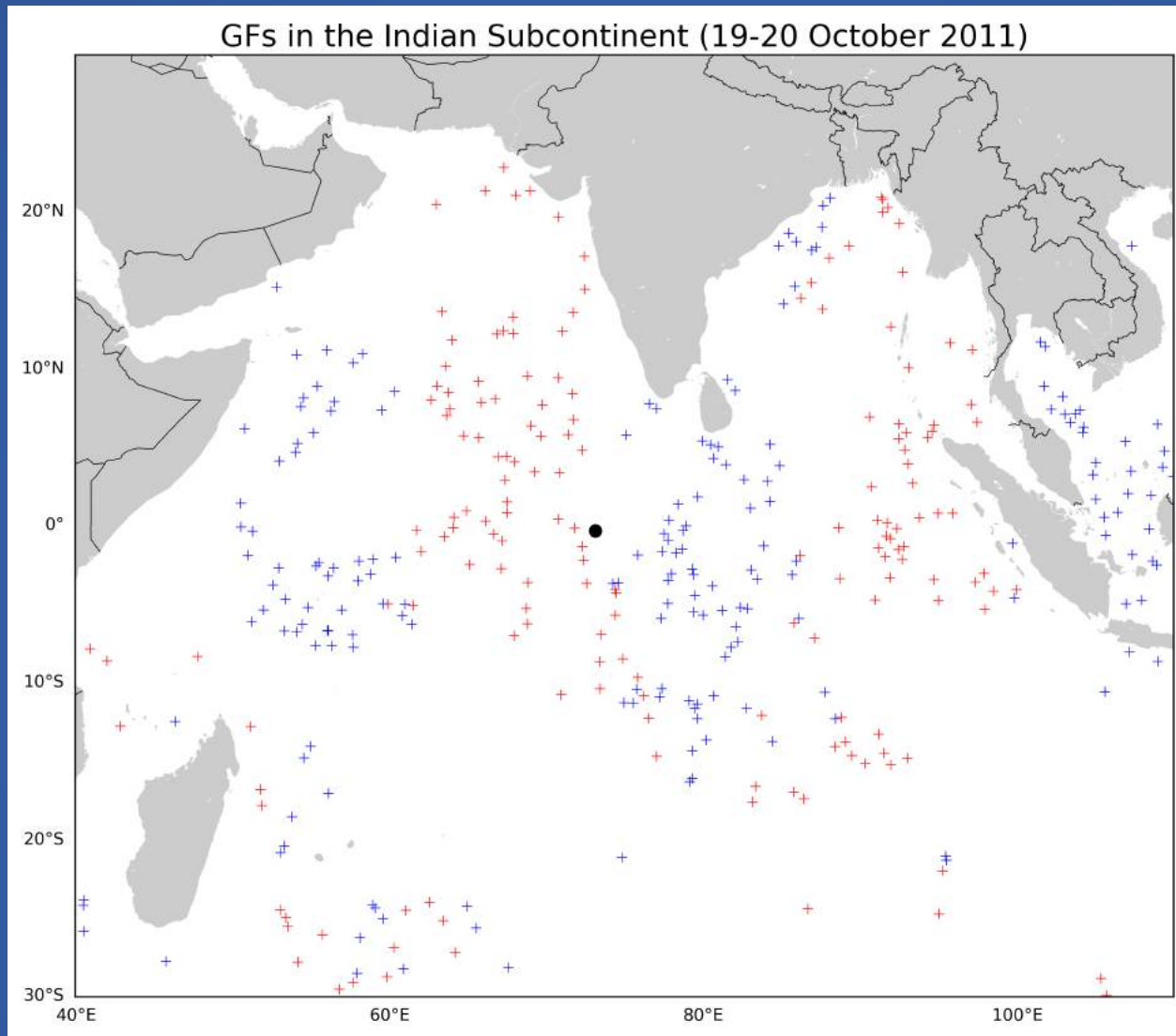


Fig. 3 GFs over the Indian Subcontinent for 19th – 20th October 2011 (DYNAMO MJO-1)

20 October 2011 16:32:17

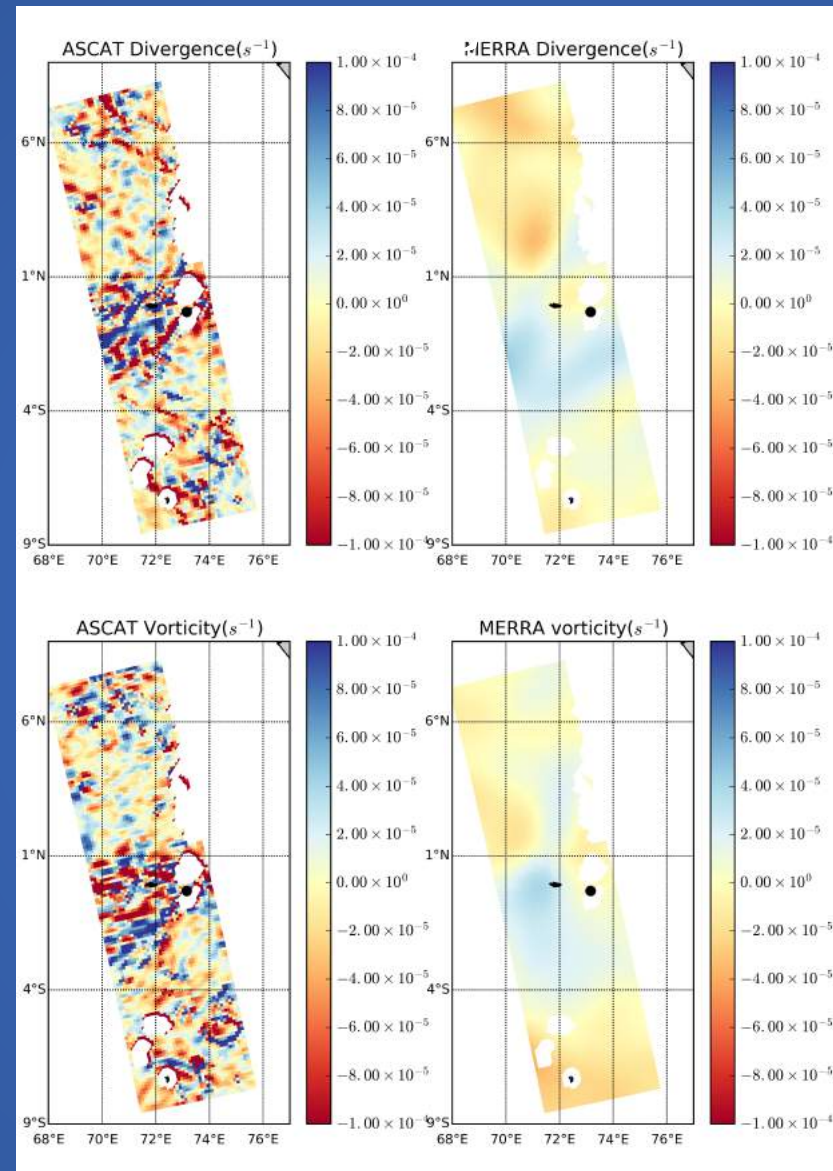
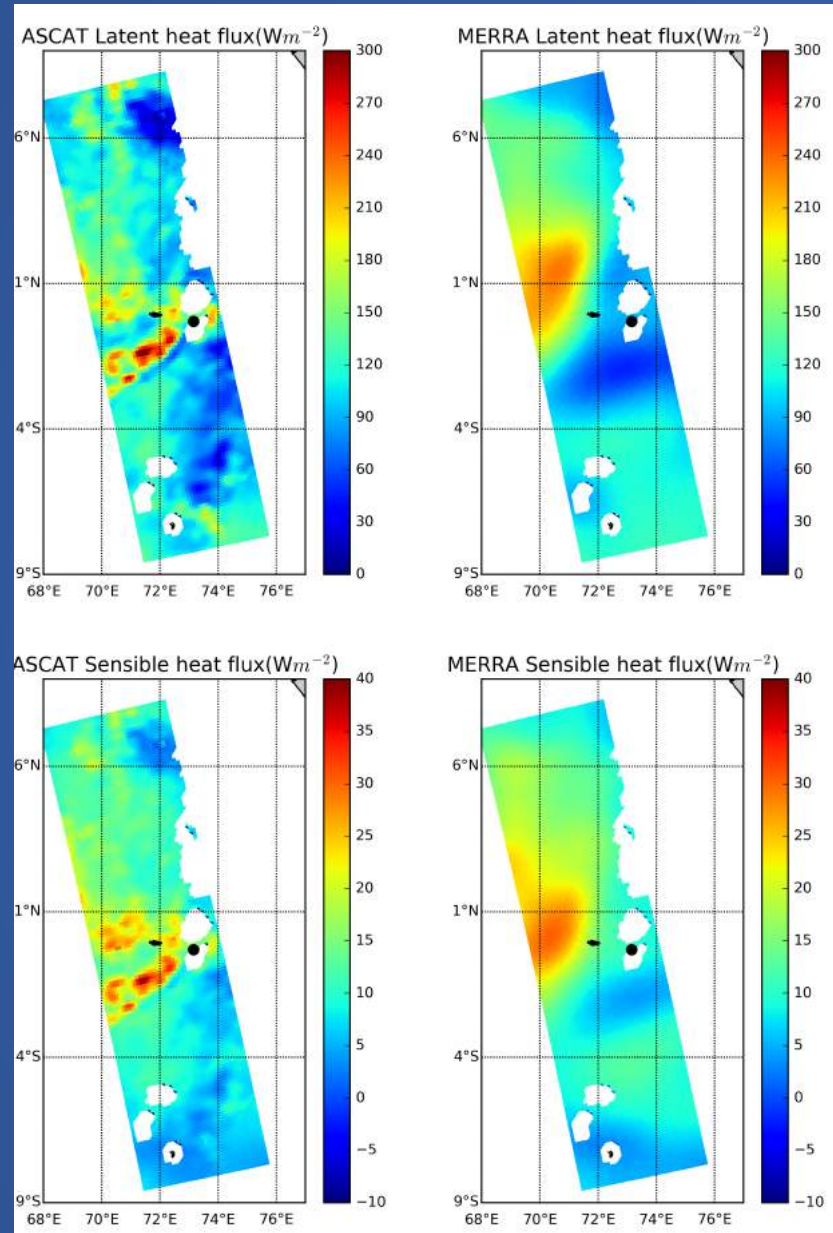


Fig.4 Divergence and Vorticity for ASCAT (left) and MERRA-2 (right)

20 October 2011 16:32:17 UTC



20 October 2011 16:30:00 UTC

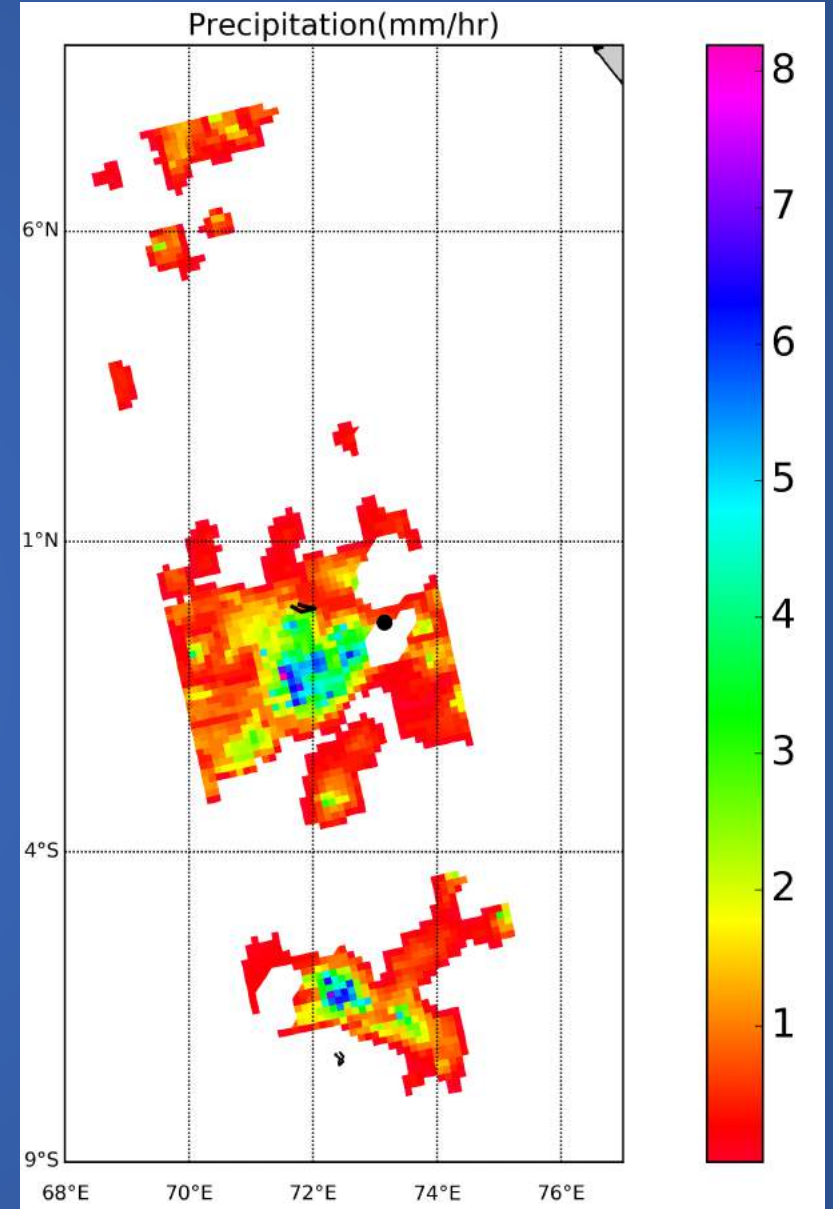


Fig.5 Surface Latent heat and sensible heat flux (Wm^{-2}) for ASCAT (left) and MERRA-2 (right) and CMORPH precipitation (mm/hr)

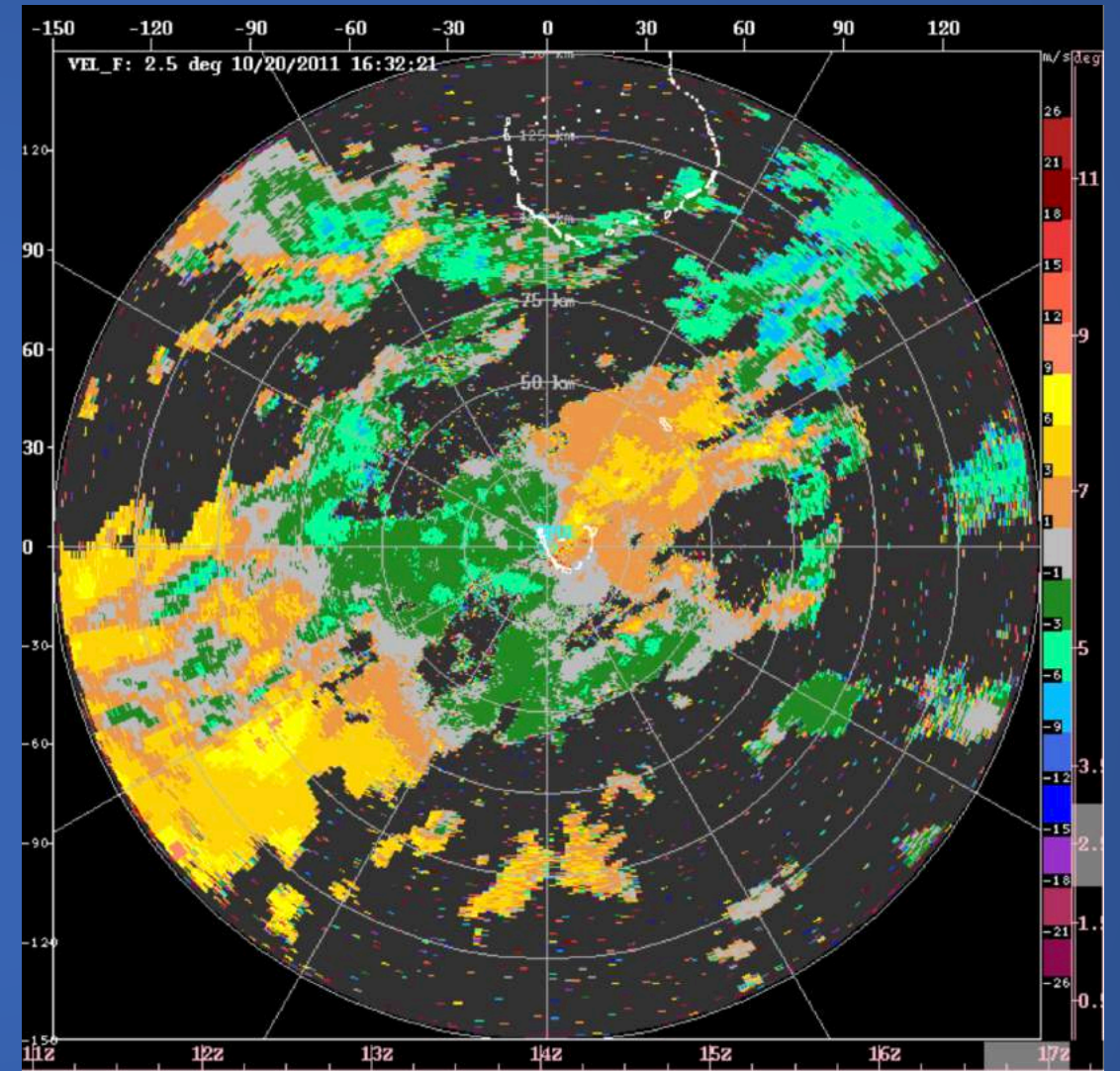
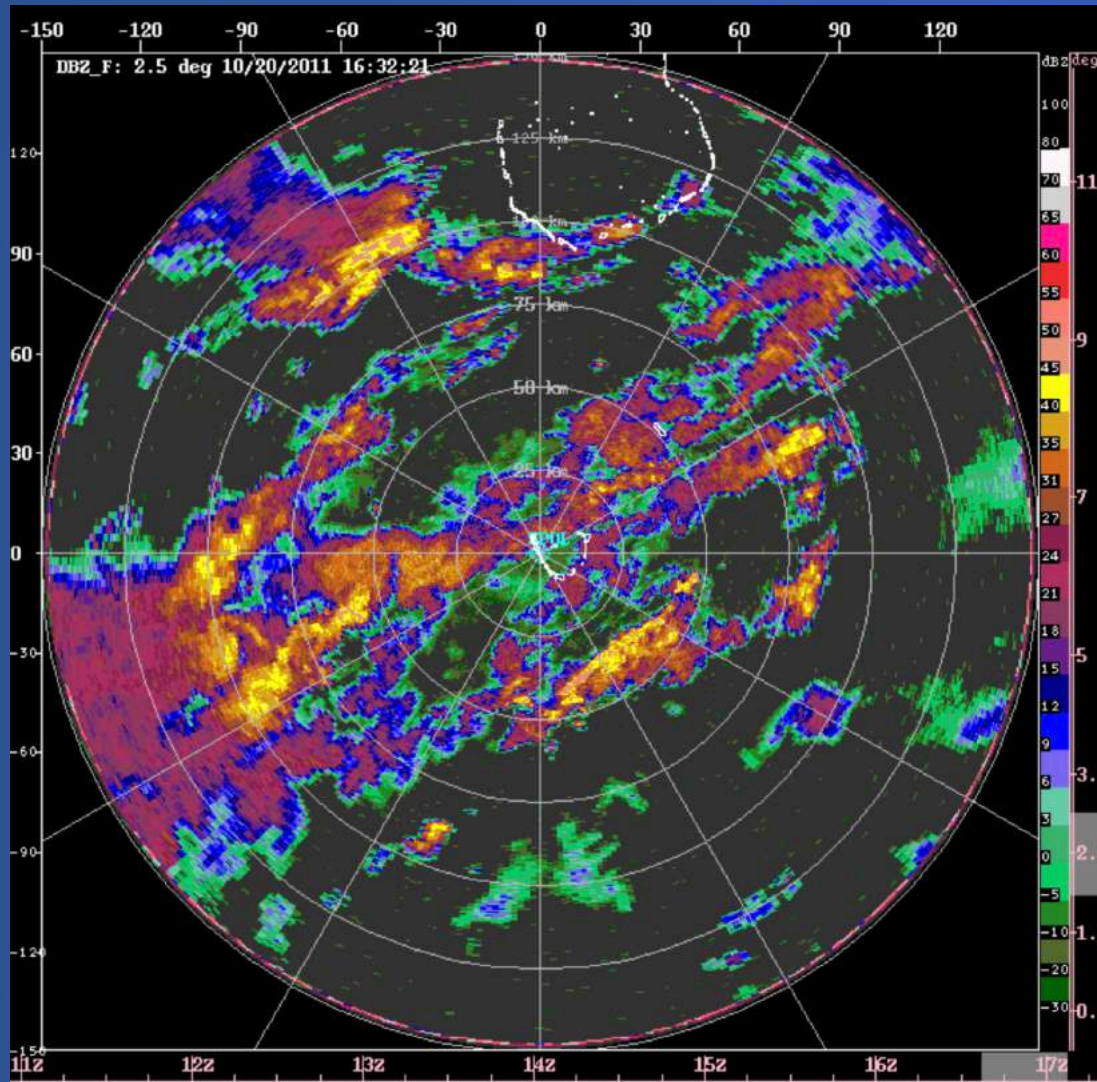


Fig.6 Reflectivity (dBZ) and Relative velocity (ms⁻¹) for 20 October 2011 16:32:21 UTC as measured from Addu Atoll during DYNAMO (2011)

20 October 2011 16:54:21 UTC

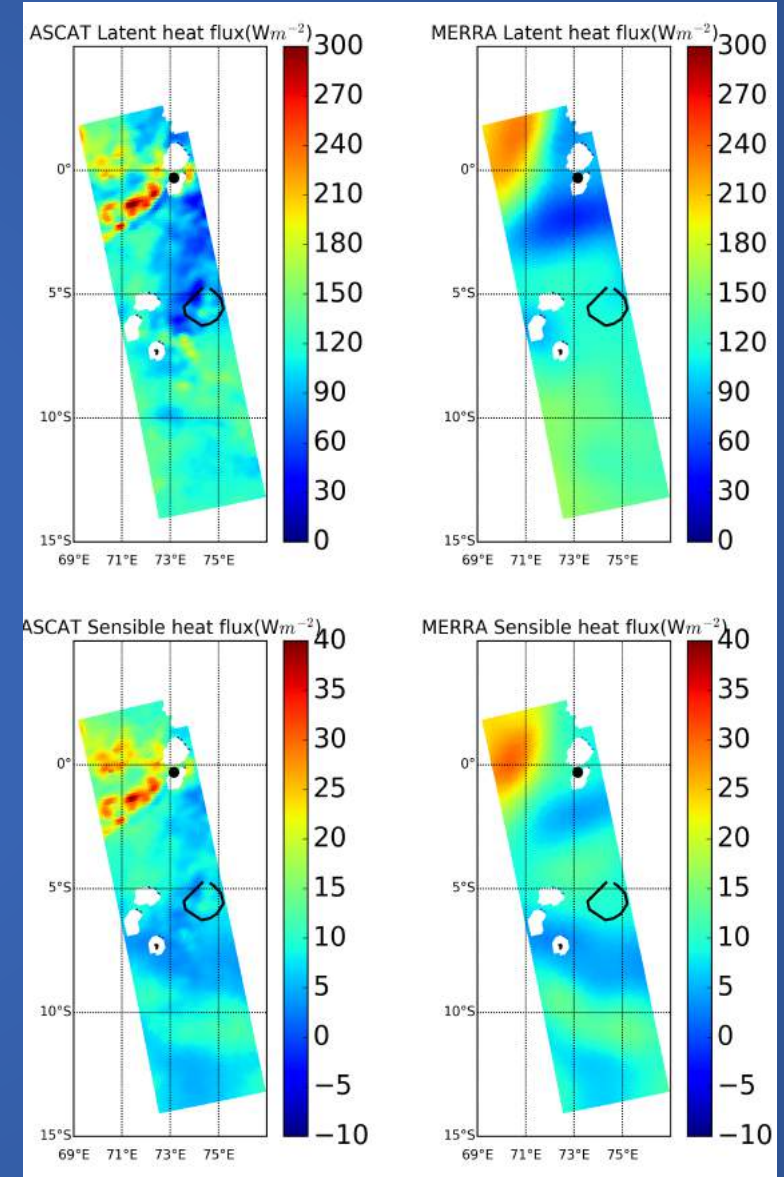
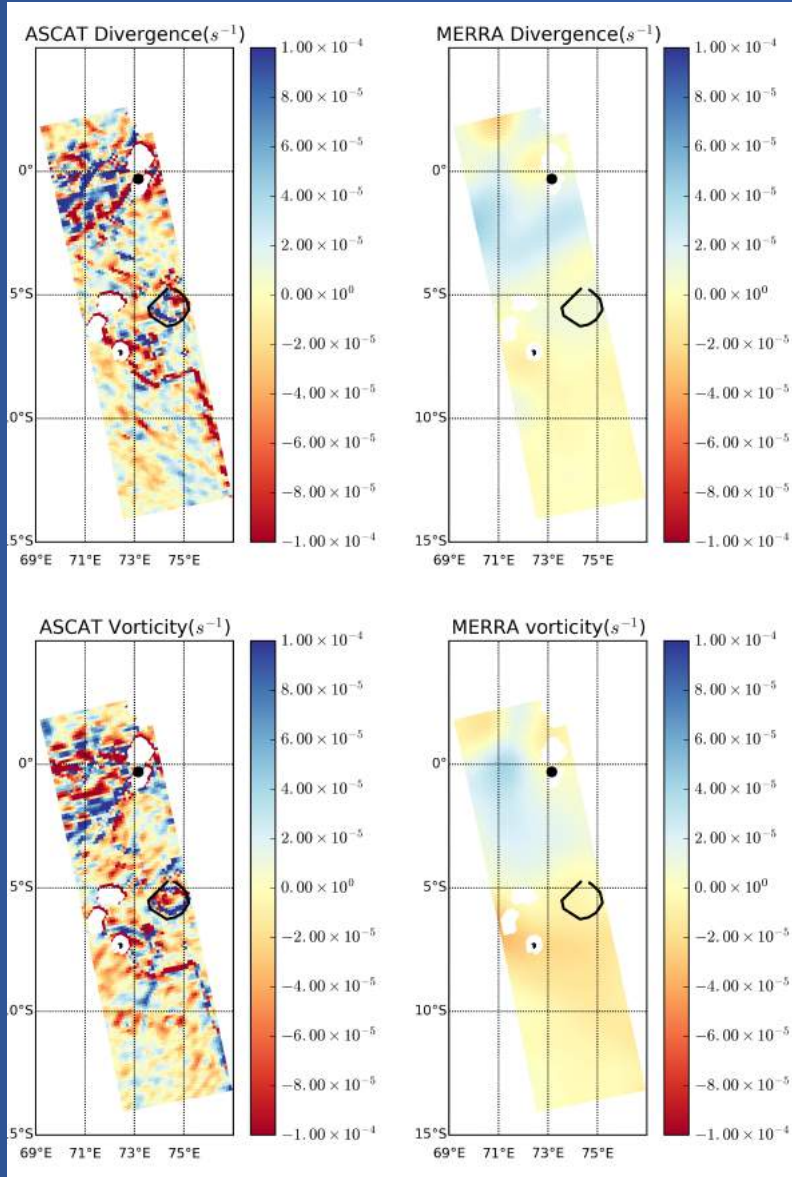


Fig.7 Divergence, vorticity and fluxes from ASCAT and MERRA

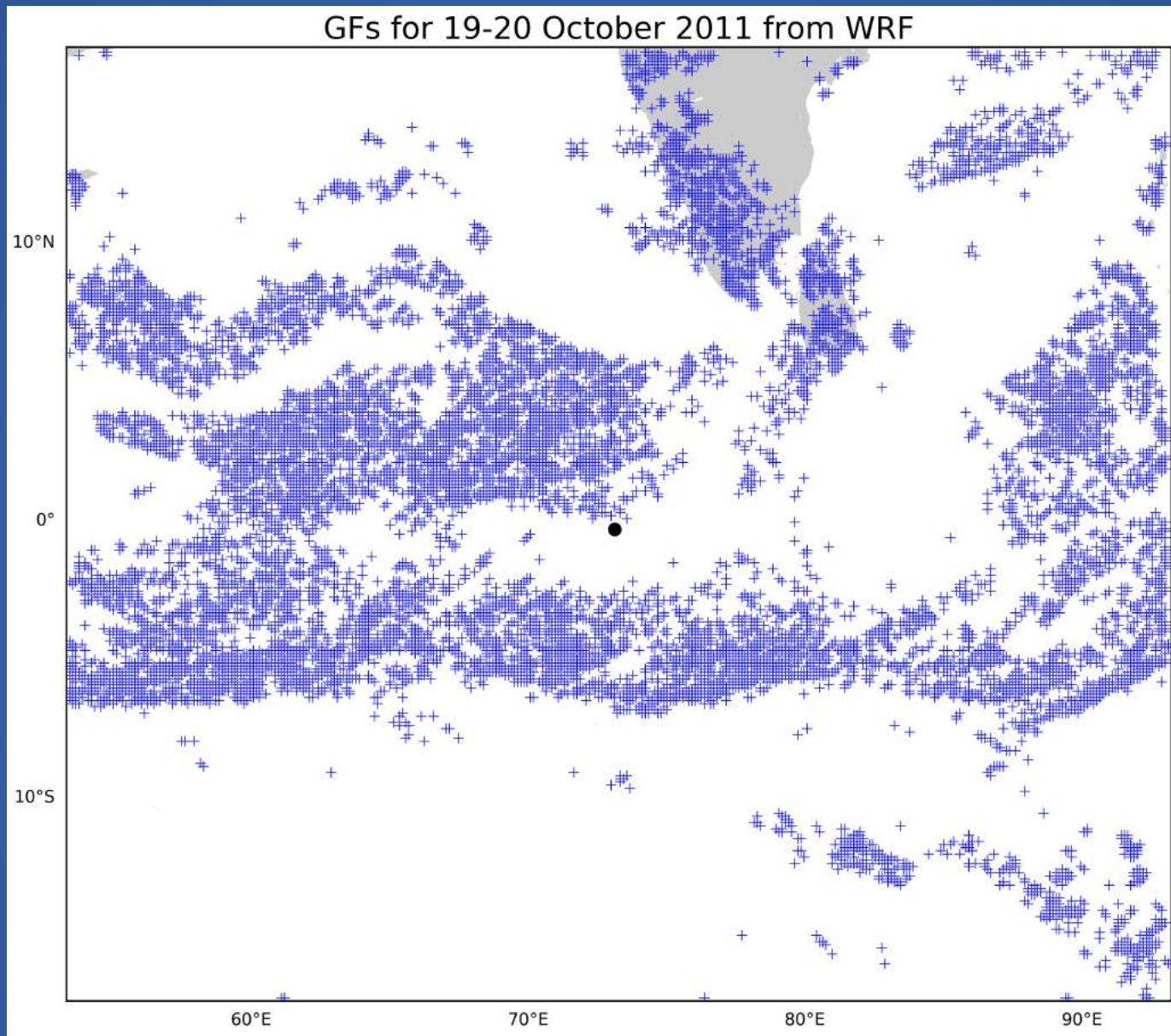
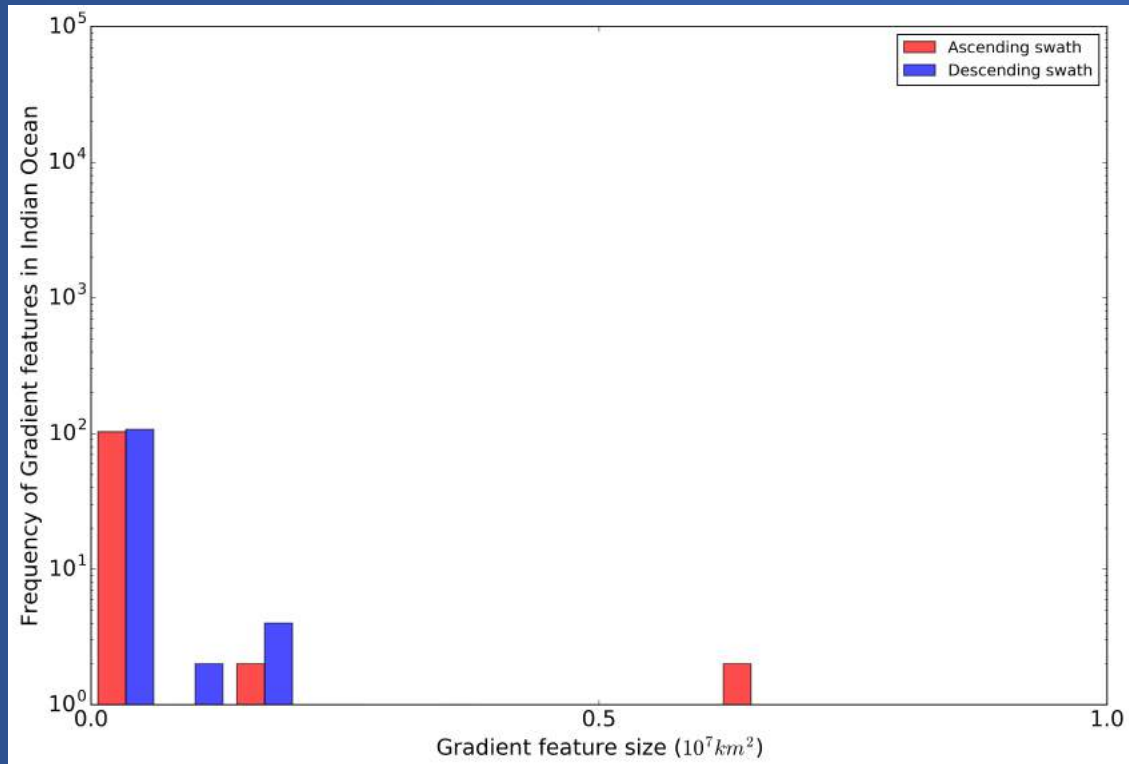


Fig.8 GFs over WRF domain for 19th -20th October 2011

ASCAT



WRF

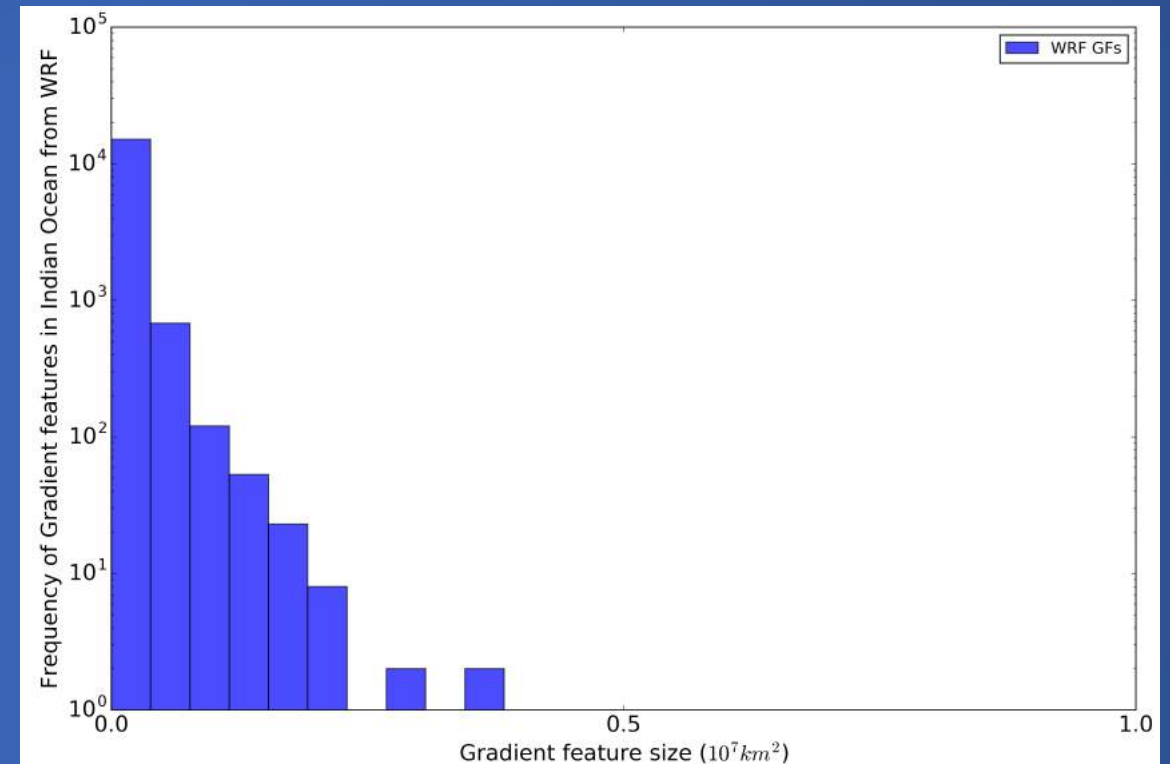


Fig. 9 Frequency of GFs over WRF domain from ASCAT (left) and WRF (right) for 19th -20th October 2011

20 October 2011 17:00 UTC

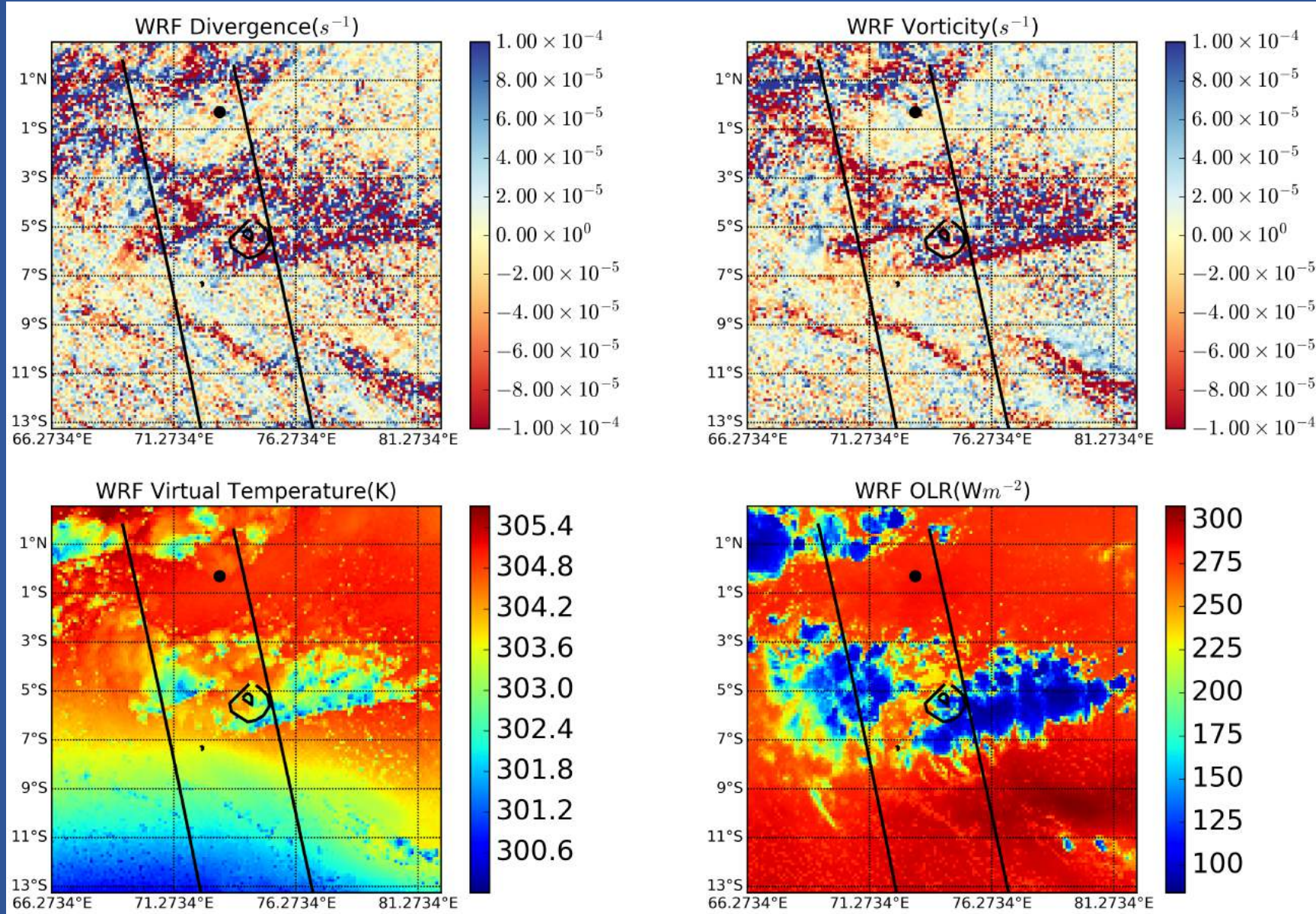


Fig.9 Divergence, vorticity, T_v and OLR for WRF Simulation with ASCAT swath overlaid

20 October 1700 UTC

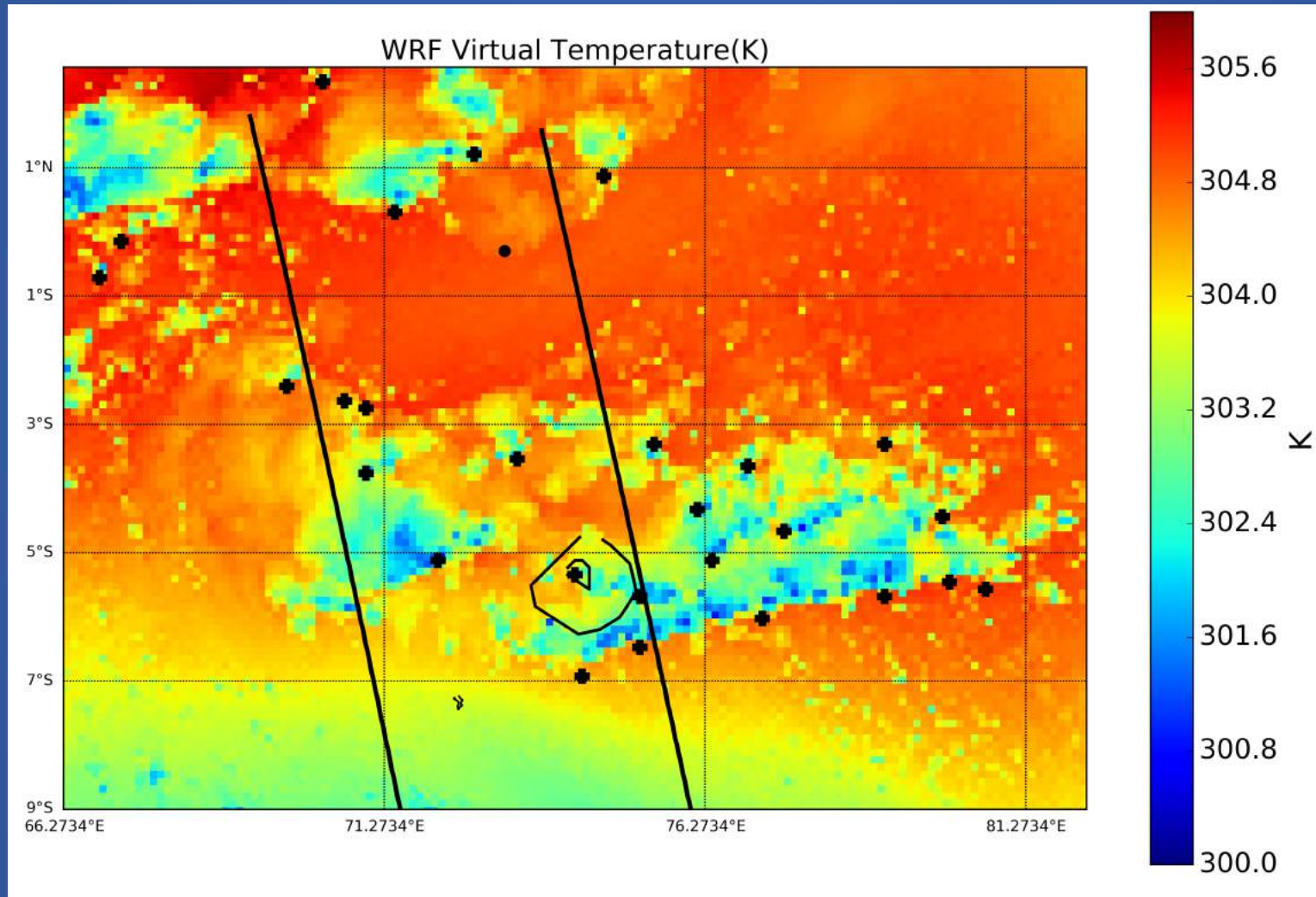


Fig.10 Virtual Temperature (K) with ASCAT swath overlaid

20 October 2011 1730 UTC

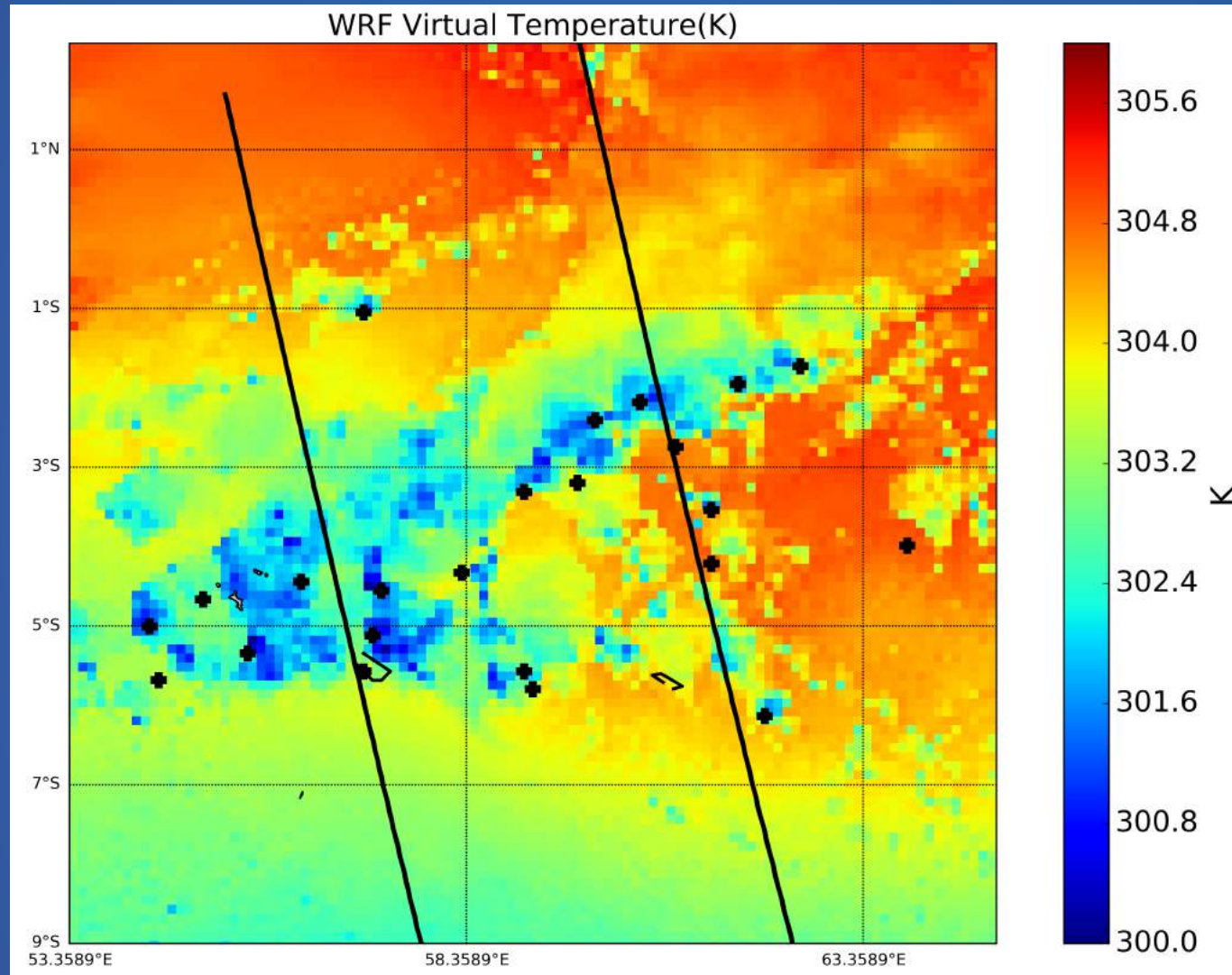


Fig. 11 Virtual Temperature (K) with ASCAT swath overlaid

19 October 2011 0430 UTC

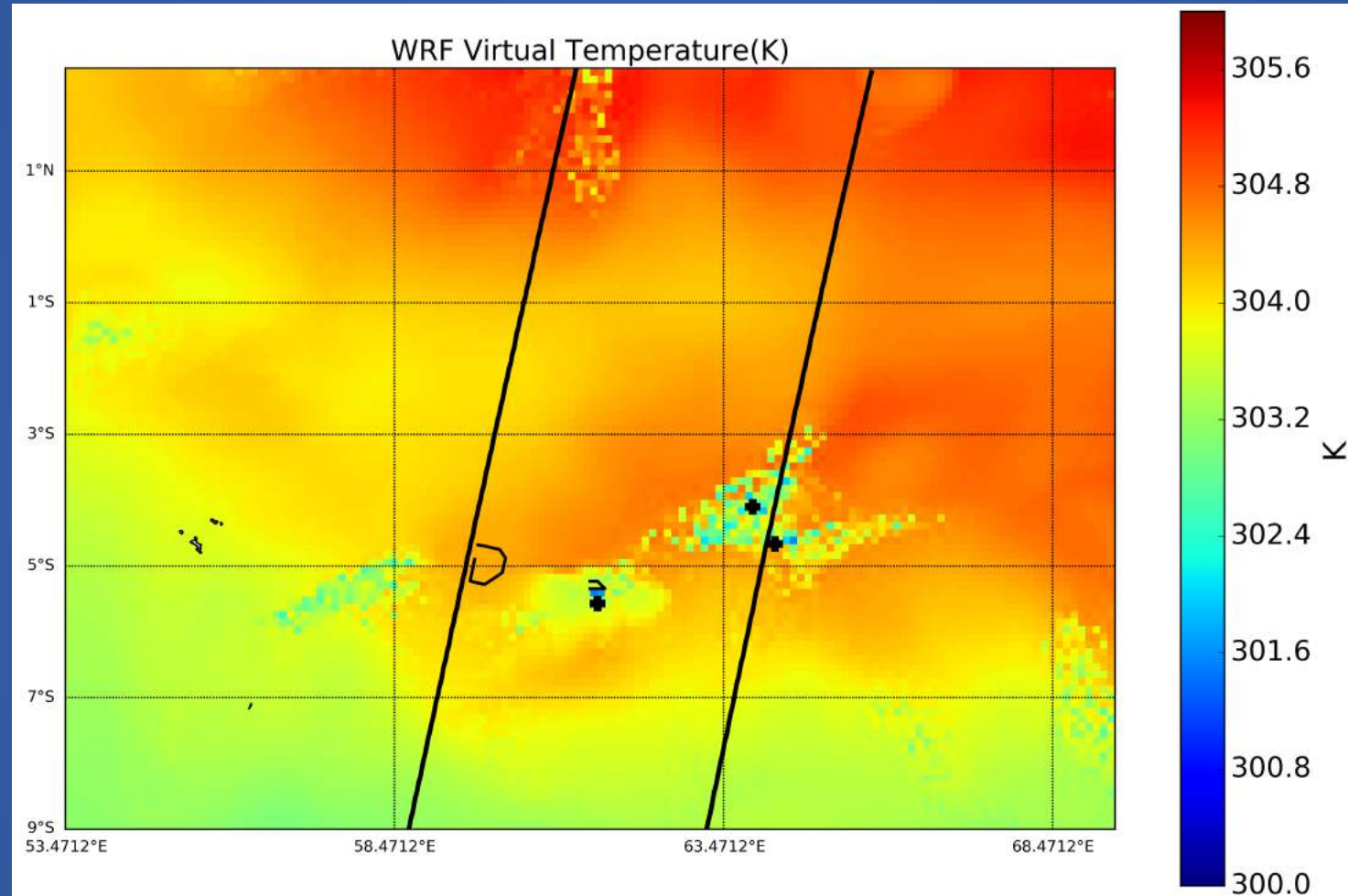


Fig. 12 Virtual Temperature (K) with ASCAT swath overlaid

19 October 2011 1630 UTC

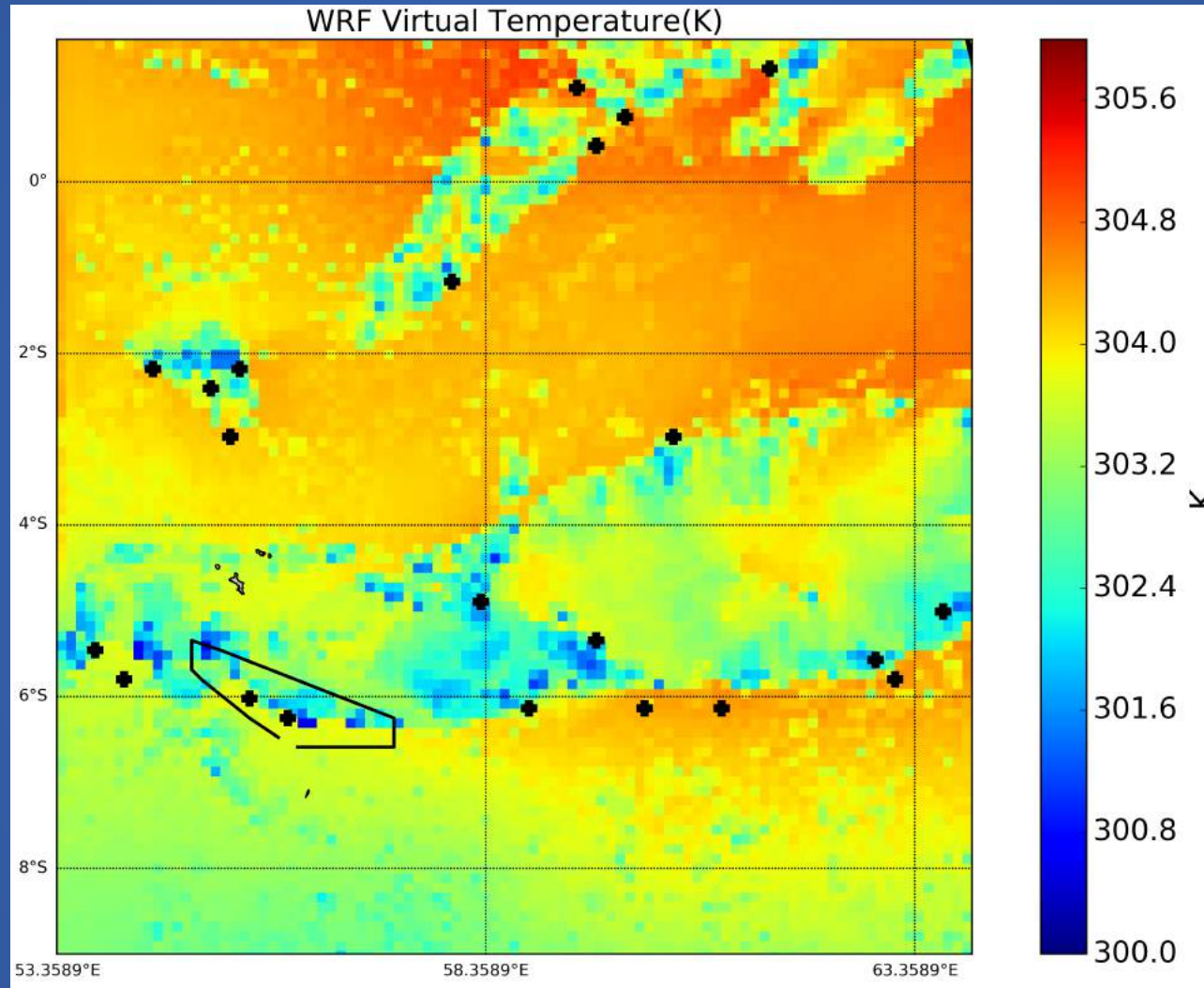


Fig. 12 Virtual Temperature (K) with ASCAT GF overlaid

Conclusions

- For 2007-2015, global density of GFs shows that these features match well with the precipitation pattern over the tropical oceans, which gives us a confidence in our hypothesis.
- Divergence and vorticity corresponding to the boundary of observed GFs gives a good picture of the outflow boundary of a mesoscale system.
- Surface sensible and latent heat fluxes calculated using ASCAT winds produce a better result as compared to MERRA-2 inherent fluxes.
- Precipitation around the perimeter of the features shows that these features are forming along the wake of the density current.

- RegridDED WRF is creating smaller cold pools overall, as compared to the climatological distribution of GFs, which might have been due to steeper gradients in wind in the model.
- WRF is not able to resolve the observed GFs very well, which might also be another reason that its producing smaller GFs.
- Low Virtual Temperature (T_v) and GFs are collocating well in WRF, thus suggesting that these features are rather cold pools.

Future Work

- We are working on a tool to match the radar and ASCAT swath for DYNAMO, so as to create a better picture of convection in the region.
- We will be running WRF with ECMWF initial conditions and will be comparing the results with the current simulation.
- We will also be including the winds from ASCAT and RapidSCAT in WRF and will study the difference in the simulations.
- We will be including more thermodynamic and dynamic parameters to study the cold pools over the global oceans.
- We will also try to run our algorithm using a mesoscale model to see whether it can resolve the cold pools comparable with ASCAT.

Acknowledgements

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Thank You!